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- J. Gurney, D. Perlis and K. Purang. "Interpreting Presuppositions Using Active Logic: From Contexts to Utterances," submitted to Computational Intelligence. 1997. (Formerly titled: Updating Discourse Context with Active Logic)

- Elizabeth Klipple and John Gurney, "A Theory of Spatial Structure for Motion-Verb Phrases: From Lexical Syntax to Meaning Representation," submitted to Second International Workshop on Computational Semantics, January 8-10, 1997, Tilburg, The Netherlands.

- Alice Kyburg and Michael Morreau, "Vague Utterances and Context Change," submitted to Second International Workshop on Computational Semantics, January 8-10, 1997, Tilburg, The Netherlands.

- Miller, M. and D. Perlis "Automated Inference in Active Logics," in *Journal of Applied Non-Classical Logics*, vol. 6, 1996, pp. 9-27.

- Morreau, M. "Fainthearted Conditionals," to appear in *The Journal of Philosophy*.

- Perlis, D. "Sources of, and exploiting, inconsistency: preliminary report," in Working Papers of Common Sense '96, Third Symposium on Logical Formalizations of Commonsense Reasoning, Stanford University, January 1996.

- D. Perlis and J. Gurney and K. Purang "Active Logic Applied to Cancellation of Gricean Implicature," in *Working Notes of AAAI 96 Spring Symposium on Computational Implicature: Computational Approaches to Interpreting and Generating Conversational Implicature*, Stanford University, March 1996.

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13. ABSTRACT (Maximum 200 words)

Our aim in this project was to explore the reasonings and representations that make natural language dialogs possible, using in particular the formalism of active logics. We continued worked on approaches using active logics to treat problems in dialog such as inference, commonsense reasoning, presuppositions and implicatures, and implemented and improved algorithms to handle these problems computationally. Extensive theoretical work was done on meta-diaalog and meta-reasoning, and how these can help resolve miscommunications in dialog; in fact, the thesis was put forward that mechanisms to corrrect miscommunicatiions are essential and central in dialog processing. Research was also done on related aspects of language and inference, particularly semantic processing of natural language discourse. We worked in these areas as well as on the design and implementation of a dialog system that exploits meta-reasoning to detect and correct errors, and a natural-language interface to a virtual-reality system at the Army Research Laboratory.

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- D. Perlis and K. Purang. "Conversational Adequacy: Mistakes are the Essence", submitted to AAAI 96 Workshop on Detecting, Repairing, and Preventing Human-Machine Miscommunication. 1996.

SCIENTIFIC PERSONNEL SUPPORTED BY THIS PROJECT AND DEGREES AWARDED:

Dr. Donald Perlis, Dr. Michael Morreau, Mr. Khemdut Purang, Mr. Mark Glezer, Mr. Carl Andersen, Dr. Elizabeth Klipple, and Dr. David Traum.

SCIENTIFIC PROGRESS AND ACCOMPLISHMENTS

Specific aims.

Our aim in this project was to explore the reasonings and representations that make natural language dialogs possible, using in particular the formalism of active logics. We continued worked on approaches using active logics to treat problems in dialog such as inference, commonsense reasoning, presuppositions and implicatures, and implemented and improved algorithms to handle these problems computationally. Extensive theoretical work was done on meta-diaalog and meta-reasoning, and how these can help resolve miscommunications in dialog; in fact, the thesis was put forward that mechanisms to corrrect miscommunicatiions are essential and central in dialog processing. Research was also done on related aspects of language and inference, particularly semantic processing of natural language discourse. We worked in these areas as well as on the design and implementation of a dialog system that exploits meta-reasoning to detect and correct errors, and a natural-language interface to a virtual-reality system at the Army Research Laboratory.

Below we summarize our results, and provide citations to the publications based on this work. Copies of these papers have been mailed separately.

Errors in Meta-dialog and Meta-reasoning

One of our central theses is that meta-dialog and meta-reasoning, far from being of only occasional use, are the very essence of conversation and communication between agents. We found four paradigm examples of massive use of meta-dialog where only limited base dialog may be present, and used these to bolster our claim of centrality for meta-dialog. We further illustrated this with related work in active logics. Moreover, there may be a core set of meta-dialog principles that is in some sense complete. If we are right, then implementing such a set would be of considerable interest. We found examples of existing computer programs that converse inadequately according to our guidelines.

Inconsistency in dialog is also an example of this. Although much effort has been expended by researchers in trying to maintain a consistent belief base

2

in formalizing commonsense reasoning, there is some evidence that the nature of commonsense reasoning itself brings inconsistencies with it. We outlined a number of sources of such inconsistencies, and discussed why they appear unavoidable. We also suggested that, far from being a roadblock to effective commonsense, (detected) inconsistencies are often a reasoner's best guide to what to do next.

In related work, we explored grounding and the sub-phenomena of miscommunication and repair from both theoretical and empirical perspectives. From a theoretical perspective, we classified several types of miscommunication, as action or perception failure, and part of a more general case of non-alignment of the mental states of agents. From an empirical perspective, we presented a preliminary analysis of examples of miscommunication in multi-modal collaboration. These points of view converge towards a predictive model of grounding, which considers costs and benefits of performing grounding acts (including repairs of miscommunication).

Inference with Active Logics

Another of our primary topics of investigation remains the application of active logics to inference and commonsense reasoning. Certain problems in commonsense reasoning appear to require the use of these non-standard formalisms. We described technical issues connected with automated inference in active logics. Control of exponential growth of inferences is a key issue. We presented a problem and its active logic solution, using a limited version of negative introspection to control inference growth. We also presented some descriptive statistics for comparison with earlier approaches.

Default Reasoning

We explored various themes in default reasoning, examining new ideas, as well as those of Brachman, Delgrande, Poole, and Schlechta. An underlying issue is that of stating that a potential default principle is not appropriate. We see this arise most dramatically as a problem in an attempt to formalize what are often loosely called "prototypes", although it also arises in other formal approaches to default reasoning. Some formalisms in the literature provide solutions but not without costs. We proposed a formalism that appears to avoid these costs; it can be seen as a step toward a population-based set-theoretic modification of these approaches, that may ultimately provide a closer tie to recent work on statistical (quantitative) foundations of (qualitative) defaults(Bacchus, Grove and Halpern). Our analysis in particular indicated the need to resolve a conflation between use and mention in many default formalisms. Our treatment proposed such a resolution, and also explored the use of sets toward a more population-based notion of default.

Presupposition and Implicature

Presupposition is a pervasive feature of human language. It involves many interesting interactions between the utterances of a discourse and the *context* of the discourse. We focussed on issues of logical form connected with the

interaction of presupposition and discourse context, and illustrated our theory with some implementational work using the *active logic* framework.

After reviewing some of the major issues in presupposition theory we turned to a largely successful unified approach of Heim. We showed how the main principles of this theory can be implemented in active logic. But we also found two serious difficulties. These consisted in (a) a straightforward counterexample and (b) a type of discourse that we call a garden-path discourse. Both the counterexample and the garden-path type of discourse can be handled by our active-logic version of Heim's theory, if reformulated and extended.

Although this work is largely theoretical, both Heim's theory and ours have important things to say about the incremental processing of the utterances that make up discourse. Our theory is a specification of a processing device that takes logical form of a sentence along with current discourse context as input and delivers an updated discourse context as output. We implemented portions of this device.

Implicature presents related problems for dialog. Dialog proceeds over time, during which inferred beliefs come and go in the listener. Yet this temporal aspect of dialog and belief is typically ignored in theoretical treatments of dialog. Using a simple example of a dialog with an implicature that arises partway through and then is later retracted, we explored how Gricean maxims and non-monotonicity may relate to each other and to a computational treatment of implicature, in order to track reasoning along Gricean lines over time. We presented our own computational approach to this, giving an implementation in the formalism of active logics.

Interaction and Control in Dialog

The topic of initiative is important to a greater understanding of collaboration aand interaction. It is a complex characterization of several aspects of dialog, relating to whose purposes are being concentrated on, and who is in "control". Initiative is important for characterizing both the cooperative and competitive aspects of dialog, including when and how to respond to the other, as well as whose agenda to follow.

Semantic Representation in Natural Language Processing

Another aspect of our work is semantic representation for natural language processing, carried out in conjunction with Dr. John Gurney and other researchers at the Army Research Laboratory in Adelphi, MD. This group is developing of a natural language (NL) processing system to be used in a virtual reality (VR) environment. The group is pursuing two lines of work: the Natural Language and Virtual Reality (NLVR) project and the natural language research program. The latter addresses basic research problems in NL processing and the former is an implementation project. The two are, in many ways, parallel and overlapping. The research generates hypotheses to be tested and the NLVR testbed provides new problems for research in NL processing and dialog.

4

With this group, we developped a computational semantic system to derive the semantic/discourse interpretation of spatial language from its syntactic form, taking into account syntactic and lexical semantic considerations, as well as the ontology of space. Our analysis has the advantage that the interpretation can be calculated fairly directly from the syntactic parse.

Under this analysis, cross-linguistic differences in the expression of spatial concepts and relations can be accounted for without discarding a spatial semantics common to all languages. We found a set of three spatial categories that apply the lexical structure in the same way that syntactic categories apply to syntactic structure. Using these categories, we developed a theory of conflation of meaning in the various spatial prepositions along with a theory of spatial functions that form the basis for a compositional semantics of sentences like "We left home through the back door", "The dogs were running around up the hill", and "We walked up the hill."

Vagueness

Another difficult problem for semantic and discourse processing is that of vagueness. We explored how vague utterances can be represented, and how we update common knowledge when we interpret vague utterances. We suggested a model of the context change required to accommodate vague utterances. It accounted for the fact that the extensions of vague adjectives like "smart" and "fat" can be stretched to suit the participants in a dialog.

Fainthearted conditionals

Inferences involving *fainthearted conditionals* were explored. These are sentences with modifiers including "normally," "other things being equal" and "provided conditions are suitable," such as:

If a dry piece of wood is heated thoroughly, then provided conditions are suitable the wood will burn.

We introduced the idea of *allowed arguments*, leading beyond the logical consequences of premises to reasonable expectations. We illustrated allowed arguments with examples involving explanations and predictions.

TECHNOLOGY TRANSFER

This project included significant interaction with Dr. John Gurney, at the Army Research Laboratory, Adelphi, MD, on a project to implement a natural language interface to a virtual reality system. Dr. Elizabeth Klipple, Mr. Khemdut Purang and Mr. Mark Glezer worked with Dr. Gurney on both conceptual and practical aspects of this effort.